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QUALIFICATION : **BACHELOR OF SCIENCE (MAJOR AND MINOR)**	
QUALIFICATION CODE: **07BOSC**	LEVEL: **7**
COURSE: **BIOMEDICAL PHYSICS**	COURSE CODE: **BPH702S**
DATE: **NOVEMBER 2023**	SESSION: **1**
DURATION: **3 HOURS**	MARKS: **100**

FIRST OPPORTUNITY: EXAMINATION QUESTION PAPER

EXAMINER: *DR VAINO INDONGO*

MODERATOR: *DR ROSWITA HAMUNYELA*

INSTRUCTIONS:

1. Answer all questions on the separate answer sheet.
2. Please write neatly and legibly.
3. Do not use the left side margin of the exam paper. This must be allowed for the examiner.
4. No books, notes and other additional aids are allowed.
5. Mark all answers clearly with their respective question numbers.

PERMISSIBLE MATERIAL:

Non-Programmable Calculator

ATTACHEMENT

Periodic Table

This paper consists of 5 pages including this front page and a Periodic Table.

QUESTION 1 [20]

1.1 Briefly discuss the following terms:

(i) Oncology (2)

(ii) Computed tomography (2)

(iii) Radiotherapy (2)

1.2 The concentration of blood passing through a vein in a human body has a diffusion constant (D = 1.4 *E-2* m^2/s). The radius and length of the vein are given as 0.08 m and 0.15 m respectively. Hint: (K_B = 1.3806 E-23 $m^2.kg.s^{-2}.K^{-1}$, T = 400 K).

(a) Compute the gradient of concentration given that $C_2 = 25\ kg/m^3$ and $C_1 = 80\ kg/m^3$. (4)

(b) Estimate the coefficient of viscosity of blood. (4)

1.3 In medical physics field, scientists apply physics concepts, theories and methods to healthcare. Stipulate four (4) physical applications applied to life sciences in **medical imaging techniques**. (4)

1.4 Stipulate two main applications of biomechanics? (2)

QUESTION 2 [20]

2.1 Derive Bernoulli's equation $P + \frac{1}{2}\rho v^2 + \rho g h = constant$. (6)

2.2 A pipe has one end/side positioned on level (h_1) and the other is tilted upward at a height h_2. The pressure values of fluid within this pipe, both on level and up, are measured as P_1 and P_2, respectively. If the fluid flow is kept at steady flow, show that the height of the fluid on the tilted end of pipe is given by $h_2 = \frac{P_1 - P_2}{\rho g}$. Which pressure is greater? (8)

2.3 Study the diagram below (Figure 1). Assume liquid in a container behaves as an ideal fluid. The pressure of still fluid inside the container and pressure of flowing fluid are the same as atmospheric pressure. A small hole is at level (2), height y_2 and the water level at (1) drops slowly at height y_1 ($v_1 = 0$). Prove that $v_2 = \sqrt{2gh}$. (6)

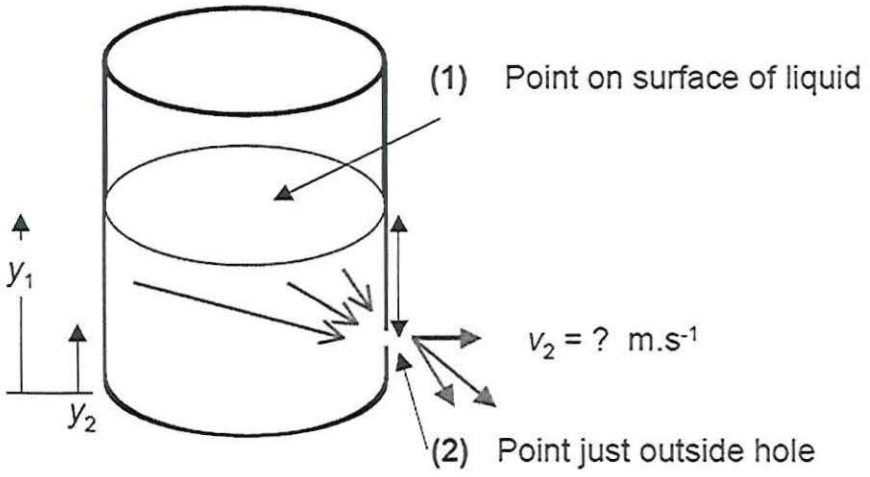

Figure. 1

QUESTION 3 **[20]**

3.1 The average velocity of ultrasound in soft tissue is 1.54*E3 m/s*. Is the value higher, smaller or similar to velocity values in bone and in lung or air. Justify your answers. (2)

3.2 A continuous pulse of ultrasound beam with frequency of 5.00*E9 Hz* was used on the patient to measure the size of a fetus. Assumption is that the patient's organ is a soft tissue ($\rho = 1.00\ ^{g}/_{cm^3}$).

Estimate the wavelength (λ) of the beam and acoustic impedance (Z). (3)

3.3 Explain, in short, the purpose of the **gel** on the patient's skin during ultrasound medical imaging. (2)

3.4 Study the following diagram (Fig. 3) depicting a ultrasound beam transversing through two media (1 & 2). P_i, P_r and P_t are incident, reflection and transmitted pressure amplitudes, respectively.

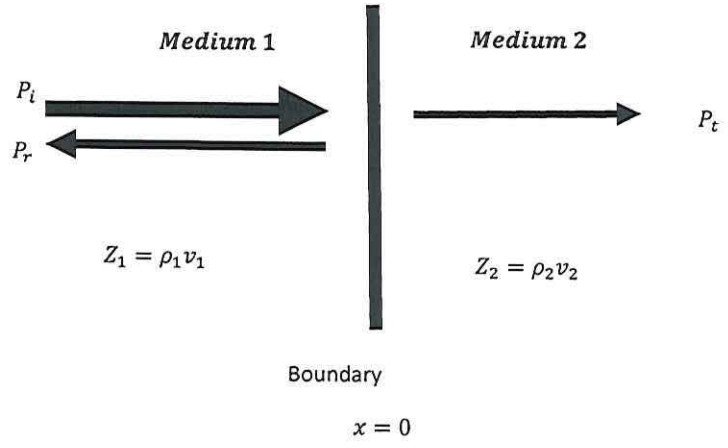

Figure 2

(i) If the ultrasound beam has wave functions k_1 and k_2 for media 1 and 2, write down the expressions for incident, reflected and transmitted acoustic pressures. (3)

(ii) Show the expressions for the acoustic velocities in the two media using the wavefunctions as in (i). (3)

(iii) Apply the principle of boundary conditions to show that $Z_1 = {}^{p_i}/_{u_i} = -{}^{p_r}/_{u_r}$ and $Z_2 = {}^{p_t}/_{u_t}$. (7)

QUESTION 4 [20]

4.1 Identify the nucleus that produces nuclear magnetic resonance signals used to take an image of a human body? (2)

4.2 A group of spins was placed into a magnetic field with 5 and 20 number of spins in the lower and upper energy levels, respectively. Calculate the energy difference ΔE between the spin states; k is Boltzmann's constant, $1.3805E\text{-}23\ J.K^{-1}$; and the temperature is 27°C. (7)

4.6 A magnetic field of 4.5 T was passed through a nucleus of a hydrogen atom, ^{1}H. Also a X-ray photon ($f = 2.5E19\ Hz$) was passed through the same atom.

Hint: Planck's constant $h = 6.626E\text{-}34\ Js$

(i) Compute the energy of a $2.5E19\ Hz$ photon? (3)

(ii) Calculate the energy of the photon that will be absorbed by a ^{1}H nucleus ($\gamma = 4.258E7\ Hz/T$) in a magnetic field? (4)

5.3 The net magnetization of magnetic resonance imaging (MRI) is set equal to zero, how long will it take for the net magnetization to recover to 80% of its equilibrium value on a sample which a T_1 of 1.0 seconds? (4)

QUESTION 5 **[20]**

5.1 State two types of x-radiations and discuss how they are produced in the x-ray tube. (6)

5.2 During radiographic imaging techniques, the quality of an image is improved by using filters, increasing the tube voltage, increasing the tube current and/or utilizing a target material with high atomic number Z. For a scan that was carried around an organ of a patient by a radiographer at a particular X-ray centre, the potential difference on the x-ray tube was 150 keV.

Sketch the diagram of ***Relative filtered intensity vs Photon energy*** showing two characteristic x-rays on high energy values of the highest peak. (4)

5.3 Briefly discuss the following terms;

(i) Effective dose (2)

(ii) Linear Energy Transfer (LET) (2)

5.4 A ^{99m}Tc generator is in transient equilibrium. The activity of Mo-99m at time t_o is 16 mBq. After 156 hrs the activity of ^{99}Mo is 3.2 mBq since there was no milking took place. Estimate the activity of the daughter nuclide. Note: ^{99}Mo, $T_{1/2} = 67\ hr$ and ^{99m}Tc, $T_{1/2} = 6.05\ hr$. (6)

END